Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

(11) (A) No 1 164 383

(45) ISSUED 840327

(52) CLASS 196-24

(51) INT. CL.^{3} C10G 1/00

(19) (CA) CANADIAN PATENT (12)

(54) PROCESS FOR RECOVERY OF RESIDUAL BITUMEN FROM TAILINGS FROM OIL SAND EXTRACTION PLANTS

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(21) APPLICATION No. 379,072

(22) FILED 810604

No. OF CLAIMS 12

Canada

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CCA-274 (11-82)

1164383

IMPROVED PROCESS FOR RECOVERY OF RESIDUAL BITUMEN FROM TAILINGS FROM OIL SAND EXTRACTION PLANTS

Abstract of the Disclosure

Bitumen in primary separation vessel underflow and bitumen plus diluent naphtha in aqueous effluent from centrifugation plants that together represent losses of 8 to 12% of oil in oil sand feed to a hot water extration plant may be substantially recovered by settling and flotation scavenging after tailings fractions have been subjected to a tumbling, mixing or shearing process. The process of the present invention includes the possibility of dilution of the sand while raising the bitumen content of the primary separation vessel underflow by admixture with centrifugation plant tailings, unscavenged primary separation vessel middlings or bituminous sludge from a retention pond, subjecting the resulting mixture to a tumbling, mixing or shearing action with incorporation of air or alternative gas bubbles followed by settling of the sand with passive or gas induced flotation scavenging of bitumen which can be promoted by use of carbon dioxide. By providing a back-up recovery system capable of efficient scavenging of residual hydrocarbon the hot water process can be operated at increased throughput, lower temperatures, reduced sensitivity to clay-water ratios and increased extraction efficiencies.

Specification

The invention relates to improvements to the process for recovery of bitumen from oil sands generally known as the "hot water process" by providing a back-up recovery system. More, particularly, the invention relates to improved methods of recovery of residual bitumen from tailings discharged from said hot water process and recovery of bitumen from sludge deposited in the waste tailings pond thereby improving the overall extraction efficiency of the hot water process.

The depletion of conventional oil reserves has renewed interest in alternative sources of hydrocarbons including the bitumen content of the oil sands (sometimes referred to as "tar sands"). Oil sands deposits are widely

distributed throughout the world and the large Athabasca deposits in Alberta, Canada are currently amenable to commerical exploitation. Extraction plants for recovery of bitumen from oil sands now in commercial operation use a process generally referred to as the "hot water process". The system includes a) mining the deposit, b) transferring the mined sand to an extraction plant, c) conditioning the sand with steam, hot water and relatively minor amounts of other conditioning reagents by tumbling in a drum mounted horizontally and capable of rotation about its longitudinal axis, d) dilution of the conditioned oil sand pulp with hot water, e) overflow recovery of bituminous froth and underflow discharge of bitumen depleted sand from primary separation vessels, f) air sparging of a "middlings" stream from the middle of primary separation vessels to produce a secondary froth and a "water-fines" effluent slurry, g) dilution of the bituminous froth with naphtha prior to removal of water and particulate matter by centrifugation as "centrifugation plant tailings", h) naphtha recovery and coking to upgrade extracted bitumen, i) recombination of bitumen-depleted effluent "water-fines" slurry from the froth flotation cells with sand and water underflow from the primary separation vessels as an aqueous "primary tailings" stream and j) transport of the primary tailings and centrifugation plant tailings for discharge to tailings ponds.

Fine mineral material, including clays not retained by a 325-mesh screen and silts which vary in quantity from 0 to 50% of the mineral solids may be deleterious to the hot water extraction process. The quantity of bitumen as a proportion of the oil sand feed is typically of the order of 12% but may vary between 0 and 18%. Sand with a bitumen content of less than approximately 6% as well as sand with a high clay content are generally considered uneconomic to process.

The relative proportions of sand, water and "process aid" entering the conditioning drums may have to be varied widely to achieve optimum bitumen recovery. A "process aid" which is used most commonly is sodium hydroxide but other alkaline reagents may be used to raise the pH of the slurry in the conditioning drum thereby reducing viscosities of the clay dispersion and producing surfactant effects. Bitumen that was originally tightly associated

with sand particles is dislodged from the sand particles during tumbling in the conditioning drum. Slurry emerging from the conditioning drum with bitumen and sand in loose association is screened to remove oversize debris and is diluted further with hot water.

Screened, hot, diluted oil sand slurry from the conditioning drum is discharged into the central region of primary separation vessels maintained at temperatures of 65 to 93°C. Most of the sand, especially the coarse sand and some bitumen, sinks to the bottom of the primary separation vessels for discharge. Effluent discharged from the bottom of primary separation vessels is made pumpable by mixing with flotation scavenged middlings. Said mixture, commonly called "primary tailings", comprising sand, silt, clay, water, process aid, and residual bitumen may typically contain 0.63% by weight of bitumen representing approximately 8.0% of the bitumen in the original oil sands feed. However, in practice somewhat higher or lower losses of bitumen to primary tailings may occur depending upon the quality of the sands and other conditions.

Relatively buoyant bitumen particles in association with air bubbles rise to the surface of primary separation vessels where they are recovered as primary froth. Bitumen particles with low rise velocity having a density close to that of the aqueous contents of the cell remain in the central region of the cell with much of the fine mineral matter. A stream of "middlings" from said central region of the primary cell is continuously withdrawn to a series of flotation cells where it is sparged with air to produce a secondary froth and an aqueous tailings stream substantially depleted in bitumen which is recombined with effluent discharged from the bottom of the primary separation cells as described below.

In normal operation the bitumen content of the total middlings is somewhat less than 3% by weight. This represents less than 10% of the bitumen in the original oil sand feed. However, the flotation scavenging system serves as an important back-up for those occasions when the recovery of bitumen in the primary separation vessels is reduced. Under such circumstances the proportion of bitumen fed to the secondary circuit can be so high as to represent 50% of the bitumen initially present in the feed. Substantially all of the

bitumen entering the flotation cells is recoverable under the vigorous aeration conditions applied therein. Therefore, losses of bitumen to primary tailings mainly occur because bitumen is entrained with the sand settling to the bottom of the primary separation vessels.

Primary tailings are removed from a "hot water" extraction plant as a slurry of about 35 to 55, typically 45% solids by weight, said solids comprising sand, silt, clay, and bitumen. The bitumen content of the slurry ranges from about 0.5 to 2.0 weight percent of the total discharge. In this specification sand is silicious material which will not pass a 325 mesh screen, silt material which will pass a -325 mesh screen but is larger than 2 microns and clay is material smaller than 2 microns. Quantities of diluent naphtha lost from the froth centrifugation may also be present. For the purpose of the present description the term "bitumen" may be used to include naphtha diluent which is generally found in effluent from the hot water process for recovery of oil from tar sands.

The bitumen content of primary froth being approximately 66% is typically higher than that of the secondary froth recovered from middlings streams which is approximately 24% bitumen. Secondary froth must be cleaned in a settler before being combined with primary froth and advanced to the centrifugation plant. In the centrifugation plant, naphtha diluted froth is centrifuged in two stages. First, larger sized mineral particles and some water are removed in a degritting stage. Much of the remaining water and fine minerals particles are then removed by a high-speed disc-nozzle centrifuge. The combined aqueous centrifugation plant effluent commonly called the "centrifugation plant tailings" contains little coarse sand but may typically contain 2.3% bitumen and 2.7% by weight of naphtha diluent in combination representing approximately 3.9% of the oil from the original oil sand feed. Although said centrifugation plant tailings contain higher concentrations of potentially recoverable hydrocarbon than primary tailings, approximately twice as much hydrocarbon is lost to primary tailings because of the larger volume of primary tailings.

Recovery of residual bitumen from both primary and centrifugation plant tailings with the same efficiency as from middlings would improve the overall

efficiency of the extraction process by approximately 7 to perhaps 12%. Furthermore, a back-up system for stripping tailings of residual bitumen (and in the case of centrifugation plant tailings recovery of residual naphtha) should allow increased throughput of the primary separation vessels and may reduce the sensitivity of the process to variations in temperature and optimum ratios of oil sand, water and conditioning agent. However, such a back-up system must be capable of reprocessing large quantities of tailings sand and recovering bitumen from a lean feedstock.

Said tailings are currently discharged into retention ponds which involve large space requirements and construction of expensive enclosure dikes. On discharge sand rapidly settles out of suspension. However, finely dispersed particles in the aqueous suspension settle only very slowly to form a sludge layer of generally increasing density at greater depths in the retention pond. Water near the pond surface may be recycled to the extraction plant.

As disclosed in Canadian Patent 841582 issued to R.A. Baillie in 1970 about 25% of the bitumen contained in the effluent floats to the top of the water almost immediately after discharge to the retention pond and after about two weeks the scum of surface bitumen consists of about 50% of the bitumen discharged to the pond. In principle said scum may be collected and returned to the process. However, higher levels of recovery are desirable although the operation of pond skimmers may be difficult during winter months.

The layer of sludge, especially sludge deep in the pond is also concentrated in bitumen as a consequence of the settling process. Said sludge may contain higher bitumen/mineral ratios than the original oil sand feed. Several patents including Canadian Patents 975696, 975698, 975699, and 975700 granted to J.H. Davitt in October 1975 propose recovery of bitumen from said sludge especially from sludge in the deep layer of a retention pond by some combination of transfer, agitation and aeration. A recent Canadian Patent, 1063957 issued to F.A. Bain in November, 1979 proposes dilution of the settled sludge from the retention pond by mixing with water with or without agitation or aeration to aid separation of bituminous material from mineral particles followed by settling and recovery of said bitumen from surface froth. In these

patents the extent of bitumen recovery and the quality of the resulting froth is unspecified but will be incomplete without either extensive agitation, aeration, or reheating.

In Canadian Patent 976901 issued in October 1975, R.A. Baillie proposes injection of pond water or pond sludge into the sand tailings layer at the bottom of a primary separation vessel to displace at least a part of the middlings stream from the interstices of said tailings layer thereby increasing the volume of middlings processed by air flotation. However, the patent proposes thereafter discarding the sand tailings layer and pond water from the separation zone. In Canadian Patent 976102 issued in October 1975, R.A. Baillie describes use or pond sludge to displace water in the sand pile resulting in overall compaction of tailings mineral but without reference to bitumen recovery.

Recovery of residual bitumen from tailings streams produced by centrifugation of naphtha-diluted froth by aeration with or without carbon dioxide after pH change is described in Canadian Patent 1000632 issued in November 1976, to S.P. Behan and D.A. Vendrinsky and 1022098 issued in December 1977, to D.A. Vendrinsky. The process requires addition of expensive chemicals and by reducing alkalinity, downgrades the quality of water with respect to recycle to oil sand conditioning drums. The problems of the loss of volatile hydro carbons and the formation of potentially explosive air/naphtha mixtures are other disadvantages of the method.

Schemes for recovery of the residual bitumen from tailings discharged from extraction plants using the hot water process can generally be classified as methods for recovery of residual bitumen from an effluent stream or streams: (a) prior to discharge to a retention pond, (b) soon after discharge to a retention pond and (c) by reprocessing pond sludge. Said methods of type (a) and type (b) have the advantage that said effluents are still warm and viscosities are relatively low but the disadvantage of dealing with lean feedstocks. Said type (c) and to a lesser extent said type (b) methods take advantage of the effects of settling to concentrate residual bitumen but lose the temperature advantage. The process of the present invention may be

operated as a type (a), (b), (c) or a combination method to increase the efficiency of the hot water process.

Description of the Invention

The method of the present invention provides for substantially quantitative recovery of residual bitumen from aqueous effluent prior to or immediately after discharge to a retention pond. The method of the present invention also provides for recovery of bitumen by reprocessing settled sludge from a retention pond formed from material discharged without adequate scavenging.

Specifically the process of the present invention exploits the discoveries (1) that turbulent shearing forces, whether induced by mechanical tumbling, by mixing, by vigorous aeration or by a combination of tumbling, mixing, and aeration can be optimized at a given temperature to disperse large bituminous agglomerates and bitumen-mineral agglomerates in tailings from the hot water process and thereby increase the efficiency with which bitumen agglomerates rise to form a bitumen-rich surface froth and (2) that carbon dioxide enhances recovery of bitumen from tailings from the hot water process.

More specifically, the present invention comprises mixing centrifugation plant tailings, unscavenged primary separation vessel middlings and/or bitumen-rich sludge from a retention pond with sand-rich underflow from primary separation vessels thereby reducing the sand content of said effluent below approximately 65 weight percent and allowing said mixture to be pumped and thereby subjected to a mechanically-induced, shearing regime, at 40 to 90 but preferably 45 to 65°C, these temperatures being achieved by controlling the proportions of the different streams or by reducing the primary separation vessel operating temperature. Shearing may be enhanced and air or gas incorporated by passing the slurry over finned surfaces designed to enhance tumbling action. The composite effluent is thereafter discharged into an appropriate settling vessel or section of a retention pond so that sand particles settle preferably through or into a layer of bitumen-depleted water or aqueous slurry such that the bitumen-containing water-fines input slurry may be displaced or partially displaced from the settling sand. Residual

bitumen is scavenged from said displaced, bituminous, water-fines slurry by quiescent settling or by gas flotation. In embodiments of the invention whereby centrifugation plant tailings containing substantial quantities of diluent naphtha lost from the centrifugation plant are treated, flotation may be accomplished using oxygen-depleted gas such as stack gas rather than air to avoid possible formation of explosive mixtures. Any carbon dioxide and sulfur dioxide in such oxygen-depleted gas would (a) reduce the frothing tendencies of aqueous slurries during flotation (b) decrease the viscosity of the bitumen-naphtha mixture present making it potentially more amenable to recovery and (c) improve settling characteristics of dispersed solids after discharge to a retention pond.

Primary and centrifugation plant tailings samples studies were taken from effluent discharge lines at the Suncor Inc. oil sand extraction plant near Fort McMurray, Alberta. Primary tailings samples were found to stratify on storage into a lower sand layer, a sludge layer comprising water, clay, silt and bitumen including fairly large bituminous agglomerates and an upper layer of relatively clear water such that stored samples were equivalent to beach, sludge, and supernatant water zones of tailings retention ponds with bituminous material being concentrated in said sludge. Centrifugation plant tailings also stratified on storage into an upper relatively clear supernatant zone and a lower sludge layer comprising water clay, silt, bitumen, and diluent naphtha. Said sludge zones were found to be readily remixed with supernatant water by stirring thereby reconstituting "water-fines" tailings dispersions. Sand zones of primary tailings could be redispersed with other tailings fractions by vigorous tumbling in a barrel mounted on an eccentric axis. After vigorous tumbling the sand-rich tailings were found to settle rapidly in a way considered equivalent to that of primary tailings discharged to a retention pond forming a lower sand layer, a "water-fines" middlings dispersion and an upper bitumen-rich froth layer. Most of the bitumen in the sand layer was part of the "water-fines" dispersion in interstitial spaces and could be readily displaced by dilution and resettling. Effects of reheating and gas flotation on transfer of bitumen from 1.0ℓ samples of such water-fines tailings dispersions to surface

froth where it can be recovered by conventional methods were studied using a 6.0 cm ID cylindrical flotation cell equipped with a fused glass frit and 2.0 mm ID stainless steel jet spargers. Gas flow was controlled by rotameters. Specific gas-liquid interfacial areas were determined from sulfite oxidation rates in parallel runs. Tailings samples were either unheated, heated prior to transfer to the flotation cell or were heated in the flotation cell by steam injection.

Table I and Figures 1, 2, and 3 illustrate phenomena relating to the process of the present invention. Table I shows bitumen distribution between (a) primary tailings fractions formed after subjecting primary tailing samples to mechanical tumbling at 20°C followed by rapid settling and (b) fractions of froth, water-fines slurry and sand after aeration of the "water-fines" fraction. Figure I shows the effect of interfacial surface area on the rate of bitumen plus naphtha recovery from aerated centrifugation plant tailings at 20°C and air flow rate in the range of 1.0 to 2.8 ℓ/ℓ.min. Figure 2 shows the use of air dispersed with a glass frit or flowing from a jet at approximately 1.0 and 20 ℓ/ℓ/min, respectively, to enhance recovery of bitumen plus naphtha from centrifugation plant tailings. Figure 3 shows the effect of carbon dioxide on the enhancement of the rate of bitumen plus naphtha recovery from centrifugation plant tailings at 20°C. Figure 4 is a schematic representation of the hot water process which illustrates embodiments of the present invention to improve the said hot water process.

When primary tailings samples are stored, for example, for more than a year to simulate retention in a pond then vigorously tumbled in a barrel mounted on an eccentric axis followed by rapid settling approximately 66% of the residual bitumen is then recoverable from surface froth, 26% is in the "water-fines" slurry above the sand and only 8% is in the sand zone (Table I). Moreover, much of the bitumen remaining in the said sand zone is not physically associated with sand particles but is part of the "water-fines" slurry occupying interstitial space and can be displaced by allowing sand particles to settle into a second water-fines slurry substantially depleted in bitumen. Furthermore, data in Table I illustrate that aeration of the water-fines

slurry resulting from the said "tumbling-rapid settling-displacement" procedure allows essentially quantitative transfer of bitumen into surface froth. As the temperature is raised to approximately 65°C less vigorous aeration for shorter times is required to get the bitumen to rise to the surface froth. Conversely, increased aeration compensates for detrimental effects of reduced temperature on bitumen recovery. Moreover, under vigorous aeration at 20°C large amounts of relatively lean froth are produced. Surprisingly, addition of carbon dioxide to the air stream at 20°C reduces "frothing" at a given air flow allowing bituminous froth to accumulate. Therefore, carbon dioxide as well as tumbling and aeration can be used to obviate or to partially obviate the need to heat or reheat tailings fractions such as pond sludge. Nevertheless, the process of the present invention provides, in addition to recovery of bitumen by tumbling and aeration with or without carbon dioxide enhancement, a simple method for reheating pond sludge by admixture with hot tailings fractions. Data in Table I and in Figures 2 and 3 is from a paper presented by Hall and Tollefson on June 11, 1979 at the First UNITAR Conference on the Future of Heavy Crude and Tar Sands in Edmonton, Alberta.

Table I: Turbulent Shearing Supplemented by Aeration With or Without Carbonation or Reheating for Recovery of Bitumen From Primary Tailings.

Treatment	Time (min)	Temp (°C)	Aeration (ℓ/ℓ/min)	Bitumen Distribution[3] Froth	Water-Fines	Sand
Mechanical Tumbling	20	20	--	--	-- --	--
Rapid Settling	2	20	--	66	26	8
Water-Fines Aeration[1]	20	20	20	73	19	8
Water-Fines Aeration	5	65	1	91	1	8
Water-Fines Aeration[2]	20	20	20	75	17	8

1. Intermittent settling required to drain voluminous lean froth.
2. Approximately 1.0% volume CO_2 in air allowed continuous aeration.
3. Approximately 80% of the bitumen present in the sand zone was removed by displacement of "water-fines" slurry from interstitial spaces by dilution and resettling.

In Figure I the rate of bitumen recovery from centrifugation plant tailings by aeration at 20°C is shown as a function of specific interfacial area. The

upturn in the effectiveness of a given interfacial area of gas at approximately 500 m^{-1} demonstrates a surprising improvement in the efficiency of a given bitumen flotation cell operated under turbulent shearing regimes at temperatures below those temperatures encountered in the hot water process. Indeed, vigorous aeration runs with an air jet shown in Figure 2 show that aeration under turbulent conditions can be used to recover more than 70% of the residual bitumen from final extraction plant tailings at temperatures between 20 and 65°C. Runs shown in Figure 2 with relatively small flows of gas efficiently dispersed with a glass frit demonstrate that even gentle aeration provides an effective means of enhancement of recovery of bitumen from tailings at temperatures within the range 40 to 80°C and especially within the range 45 to 70°C. The process of the present invention provides methods for subjecting such tailings to turbulent shearing conditions.

Data in Figure 3 illustrate that carbon dioxide acts much like a rise in temperature in improving the rate of bitumen recovery from final extraction plant tailings at 20°C. Therefore, carbon dioxide can be used to enhance bitumen scavenging from tailings especially at temperatures below the normal 65 to 92°C operating range for primary separation vessels. Achievement of efficient flotation scavenging of residual bitumen or bitumen plus naphtha from aqueous tailings slurries at temperatures well below the normal operating range of the hot water process by use of turbulent shearing and/or contacting with carbon dioxide is the discovery exploited in the process of the present investigation.

As a means of further defining the process of the present invention the drawing in Figure 4 attached hereto illustrates two preferred embodiments of the present invention.

Example I

With reference to Figure 4, conditioned and diluted oil sand slurry is introduced into a primary separation vessel 1 of conventional design operating within the conventional temperature range 65 to 92°C. In terms of the proposed process involving improved scavenging systems that operate in the range of 40 to 80°C this temperature range could be broadened to 40 to 92°C. Flotable

bitumen rises to the surface of vessel 1 to form a layer of primary bituminous froth. A middlings stream is withdrawn through conduit 2 to a secondary separation unit 3 which comprises one or more flotation cells. Secondary froth from unit 3 is withdrawn through conduit 4 to a froth settling vessel 5 where the mineral and water content is reduced before said secondary froth is transferred through conduit 6, combined with primary froth and diluted with naphtha in conduit 7 prior to centrifugation in one or more stages in a centrifugation plant 8 to separate diluted bitumen from water and mineral. Diluted bitumen is stripped of diluent prior to further upgrading. Aqueous tailings from the centrifugation plant 8 may be transferred through conduit 9 and mixed with sand-rich underflow from the primary separation vessel 1 so as to increase the pumpability and bitumen content of said sand-rich underflow instead of being discharged directly to a tailings pond. A portion of the middlings stream from the secondary separation vessel 3 may be transferred through conduits 10 and 9 to further dilute sand-rich underflow from vessel 1 in conduit 13. Note that by providing scavenging capability the proposed process introduces flexibility in operation of vessel 1 with respect to mineral-water ratios as well as temperature. Furthermore, diversion of a portion of the unscavenged middlings stream from conduit 2 through conduit 14 to conduit 13 would decrease the required capacity of flotation scavenging units 3. In the embodiment of the present invention illustrated by example 8 there would be no input of pond sludge to mixing zone 13 through conduit 34 because bitumen is efficiently recovered prior to discharge of tailings to retention ponds. After said mixing in conduit 13, a composite aqueous stream is obtained comprising sand, water, process aid, silt, clay, bitumen and diluent naphtha. Said stream is subjected to further turbulent shearing regimes in a tumbler, mixer, screw conveyor or with a pump 17 and finned section of pipe 18 as depicted in Figure 4 with or without aeration through line 20 prior to discharge into secondary separation vessel 19. Said secondary separation vessel 19 may preferably be a fixed vessel with or without vertical partitions but could also be a boomed and skirted mobile section of a diked retention pond.

Incorporation of air or other gases into tailings in turbulent shearing

zone 18 would normally be the primary source of gas bubbles required for formation of a surface layer of bituminous froth in secondary separation vessel 19. Bituminous froth recovered from the top of said separation vessel 19 is transferred through conduit 23 and combined with secondary and primary froth streams or may be processed separately. Air or flue gas may be introduced through line 22 into one or more sand-depleted sections of separation vessel 19 so as to increase yields of bituminous froth overflowing vessel 19 thereby reducing aeration requirements for a middlings layer comprising water, silt, clay, naphtha and bitumen drawn through conduit 24 for flotation scavenging in units 16. Indeed by use of internal divisions or baffles conduit 24 may be eliminated such that flotation units 16 become an integral part of separation vessel 19.

A refinement to operation of the sand settling-bitumen flotation system 16-24-19 would be to introduce, through conduit 12 near the bottom of separation vessel 19, a suitable bitumen depleted water-fines dispersion comprising effluent from flotation cells 3 or 16 through conduits 10 and 12 or 30 and 31 respectively, so as to displace or partially displace bituminous slurry from the intersticies of settling sand. Pond sludge from zone 15 could also be used for this purpose.

Naphtha diluent will be present in tailings discharged from centrifugation plant 8. Therefore, gas vented through conduit 27 from separation vessel 19 and flotation units 16 may contain light hydrocarbons which may be recovered using condensers or a bed of activated carbon 28 or by other conventional means. The potential flammability of said air-hydrocarbon mixtures can be eliminated by using oxygen-deficient stack gas, with or without recycle through conduit 29 and comprising nitrogen, water vapor, carbon dioxide and small portions of sulfur dioxide in place of air in conduits 20, 22 and 26.

Apart from flammability considerations, surprisingly it has been discovered that sparging of effluent from centrifugation plant 8 with gas rich in carbon dioxide increases the rate of formation of bituminous froth and therefore reduces residence times required for flotation scavenging of said effluent. It has also been discovered that carbon dioxide reduces froth

volumes during aeration of the primary tailings fraction from which sand has been allowed to settle. Furthermore, to the extent that the pH of aqueous effluent is reduced by addition of carbon dioxide or sulfur dioxide, the settling rate of fine material particles suspended in the effluent is increased thereby reducing the residence time in the retention pond required for partial clarification prior to recycle of process water 37.

Major advantages of the process of the present invention operating in accord with the embodiments illustrated in Example I are provision of a back-up recovery system thereby allowing 1) increased throughput in primary separation vessels under suboptimal conditions of temperature or mineral-to-water ratios, 2) essentially quantitative recovery of bitumen with reduced naphtha losses and 3) reduced operating temperatures.

Example II

The process of the present invention may, also be used for reprocessing of settled or partially settled pond sludge and preferably sludge from zone 35 deep in a retention pond that was formed by discharge of primary tailings, centrifugation plant tailings or a mixture of primary and centrifugation plant tailings that had not been effectively treated to recover residual bitumen or bitumen and naphtha prior to discharge. Therefore it must be clearly stated that deep pond zones 15 and 35 in Figure 4 represent two types of sludge, one of low bitumen content formed from discharge of tailings depleted in bitumen according to the process of the present invention and the other rich in bitumen formed from discharge of tailings containing recoverable amounts of residual bitumen or bitumen and naphtha.

As an aid to transport of said bituminous sludge through conduit 34 to mixing zone 13, dilution with warm tailings water such as effluent from conduit 10 may be advantageous. The effects of mixing settled pond sludge with primary tailings or with primary tailings plus centrifugation plant tailings would be 1) to raise the temperature of the bituminous sludge thereby minimizing tumbling and aeration requirements for essentially quantitative bitumen recovery from said sludge and 2) to increase bitumen-to-sand ratios and therefore to increase bituminous froth outputs from scavenging units operated according to the process

of the present invention. It is envisaged that such an embodiment of the process of the present invention would be useful for 1) reprocessing sludge from older ponds, 2) reprocessing sludge formed during winter months when use of a mobile boom and skirt version of vessels 19 or 19 and 16 would be impractical or 3) processing only one stream from a dual extraction plant prior to discharge to a retention pond but at a later time reprocessing bituminous pond sludge derived from untreated tailings from the second process stream. After enrichment of hot, sand-rich tailings in conduit 13 by addition of bituminous sludge from conduit 34, tailings mixture is subjected to a turbulent shearing regime, aeration, flotation and settling as described in Example I.

The two examples of the process of the present invention are meant to illustrate but not to limit embodiments of the process of the present invention. For instance, it may be advantageous to process centrifugation plant tailings by an analogous tumbling, mixing, shearing or gas mixing process in an appropriately closed system but not involving mixing with primary separation vessel underflow or by mixing with only a small fraction of primary separation vessel underflow. It is also to be understood that conduits and vessels represented in Figure 4 may be multiple units.

Claims

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1) A process for enhanced recovery of bitumen or bitumen and diluent naphtha from aqueous tailings associated with the hot water extraction of bitumen from oil sand comprising:

a) Combining sand-rich effluent discharged from the bottom of primary separation vessels comprising sand, water, silt, clay, process aid and residual bitumen with other bitumen or bitumen and naphtha containing tailings fractions or streams such that the sand-water ratio is reduced and pumpability of said sand-rich effluent is improved and such that the bitumen content of the resulting composite tailings stream is generally greater than the bitumen content of said sand-rich effluent normally discharged from the bottom of conventional primary separation vessels.

b) Subjecting said composite tailings stream to a tumbling, mixing, or shearing process whereby bituminous agglomorates, whether substantially bitumen or comprising composites of bitumen or bitumen and naphtha with mineral particles are substantially dispersed and whereby air or other gases are introduced into the aqueous slurry.

c) Discharging said slurry into a separation zone or vessel wherein bituminous froth rises to the surface where it can be recovered, wherein sand settles downward for discharge and a water-fines slurry comprising water, silt, clay, process aid and bitumen or bitumen and naphtha is partially displaced as the sand settles and may be further displaced from the sand by injection of another water-fines slurry of relatively low to zero bitumen content.

d) Subjecting said displaced water-fines slurry, which may be withdrawn to separate flotation cells, to flotation scavenging by contacting with air or other gas streams and especially with carbon dioxide-

enriched, oxygen-depleted gas so as to produce a further yield of bituminous froth.

e) Discharge of the lower sand-rich aqueous tailings comprising water, sand, silt, clay, and process aid, but substantially depleted with respect to bitumen or bitumen plus naphtha.

2) A process as defined in claim 1 in which the bitumen and naphtha-containing tailings fraction of part (a) comprises centrifugation plant tailings.

3) A process as defined in claim 1 in which the bitumen-containing tailings fraction of part (a) comprises middlings from a primary separation vessel that have not been subjected to flotation scavenging.

4) A process as defined in claim 1 in which the bitumen or bitumen and naphtha-containing tailings fraction of part (a) comprises sludge from a retention pond and especially sludge from a zone deep in a retention pond in which bitumen or bitumen and naphtha has been concentrated by settling and in which the temperature of said pond sludge is raised by mixing with warm tailings fractions.

5) A process as defined in claim 1 in which a tumbling, mixing, or shearing action described in part (b) is induced by a rotating drum, cylinder or tumbler partially filled with air or an alternative gas.

6) A process as defined in claim 1 in which the tumbling, mixing or shearing action described in part (b) is induced or partially induced by a pump or series of pumps.

7) A process as defined in claim 1 in which the tumbling, mixing or shearing action described in part (b) is induced by a pump or series of pumps forcing said aqueous slurry through a pipe or over a series of fins, baffles or internals such that turbulence is increased and contacting of air or an alternative gas with said aqueous slurry is enhanced.

8) A process as defined in claim 1 in which the settling zone described in part (c) comprises a vessel equipped to collect froth overflow, discharge underflow and discharge a water-fines slurry from the middlings section; said vessel may be equipped for injection of displacement slurry into downward settling sand; said vessel may also feature compartmentalization by one or more vertical baffles such that air or alternative gas may be injected near the bottom of one or more of said compartments so as to increase the yield of bituminous froth and progressively remove bitumen from "water-fines" slurry prior to discharge.

9) A process as defined in claims 1 and 8 in which the settling zone is a mobile, boomed and skirted section of a tailings retention pond.

10) A process as defined in claim 1 and 8 in which water-fines slurry injected into sand in the lower part of said settling zone comprises retention pond sludge or a slurry of water, silt, clay, and process aid recovered as output from flotation cells used to scavenge residual bitumen or bitumen and naphtha.

11) A process as defined in ~~claims 6, 7, 8 and 10~~ claim 1, part (d) in which said alternative gas is enriched in carbon dioxide or depleted in oxygen relative to air and especially in which said alternative gas is flue gas.

12) A process as defined in Claim I in which the temperature of the slurry in bitumen scavenging system is between 20 and 93°C.

FIGURE 1

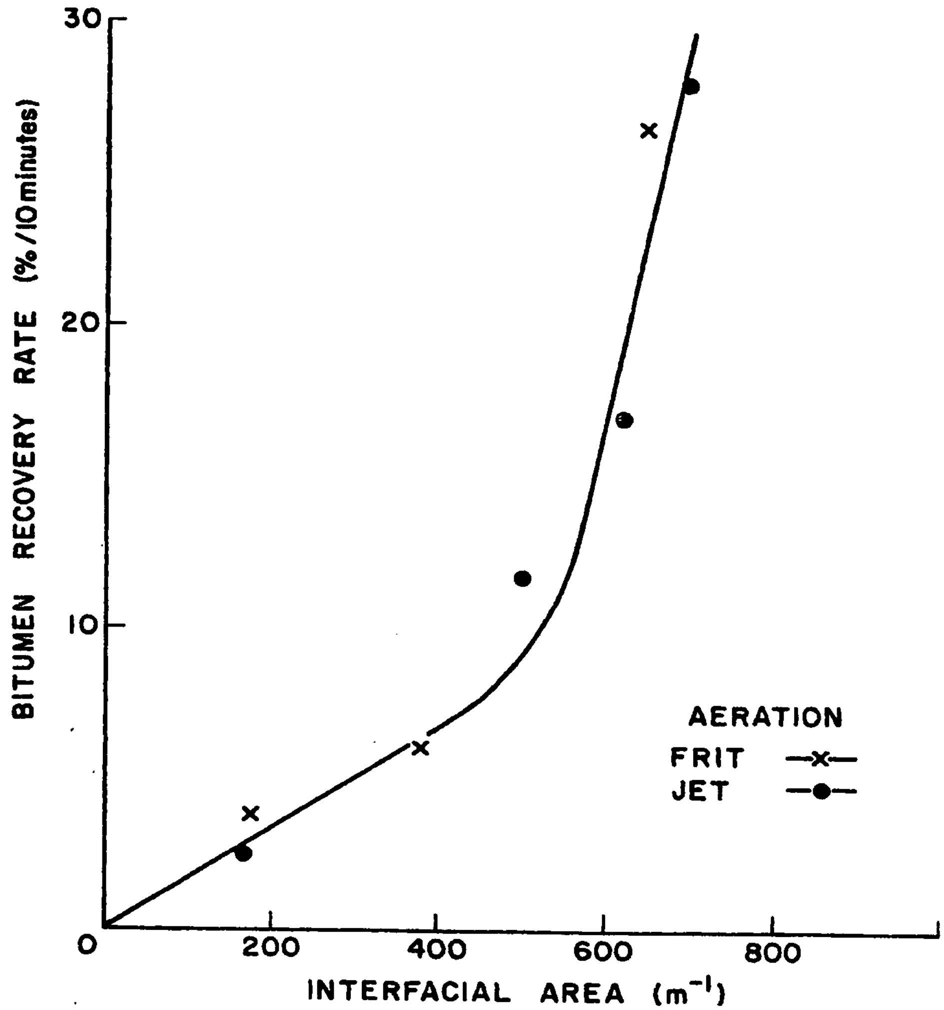

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FIGURE 2

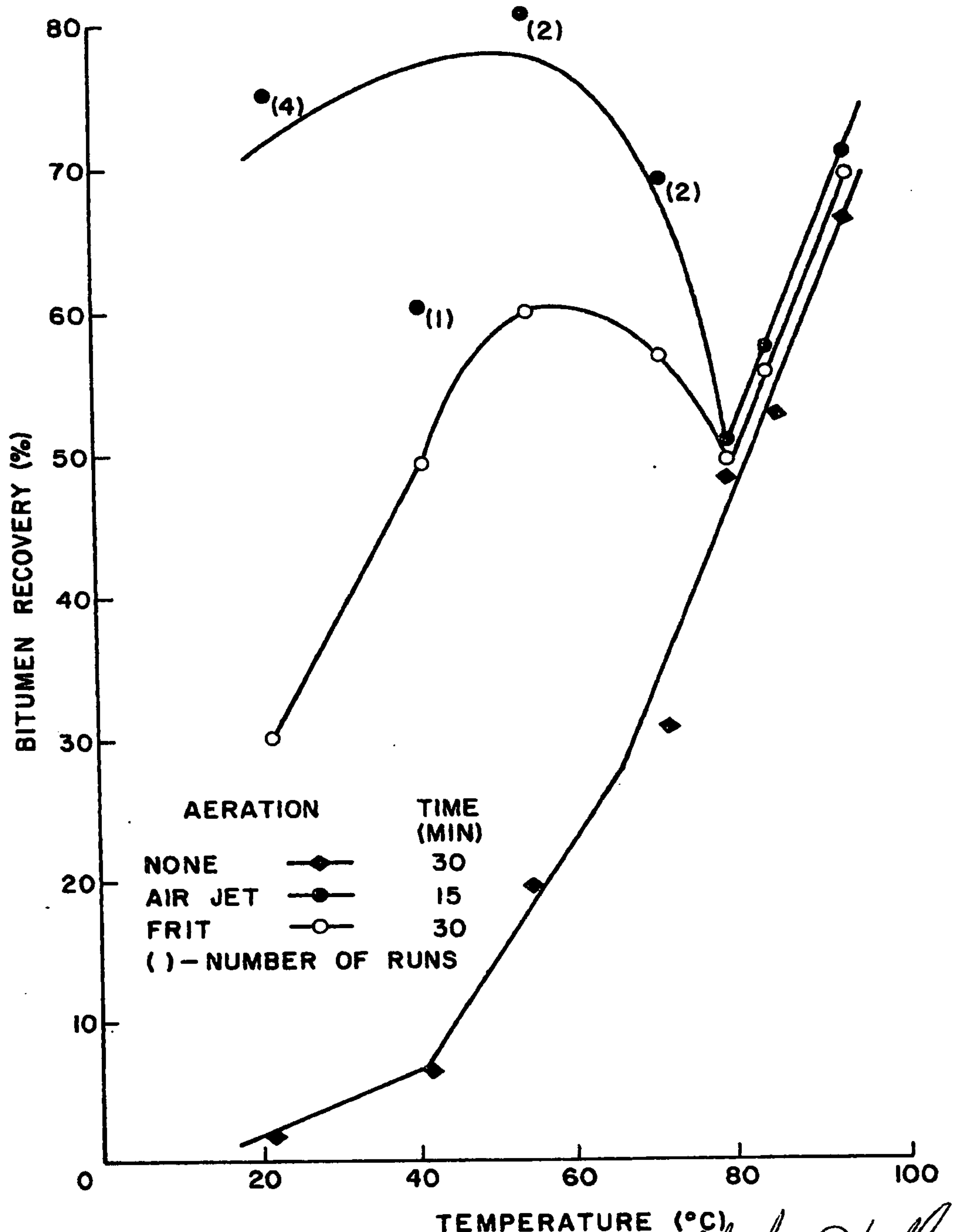

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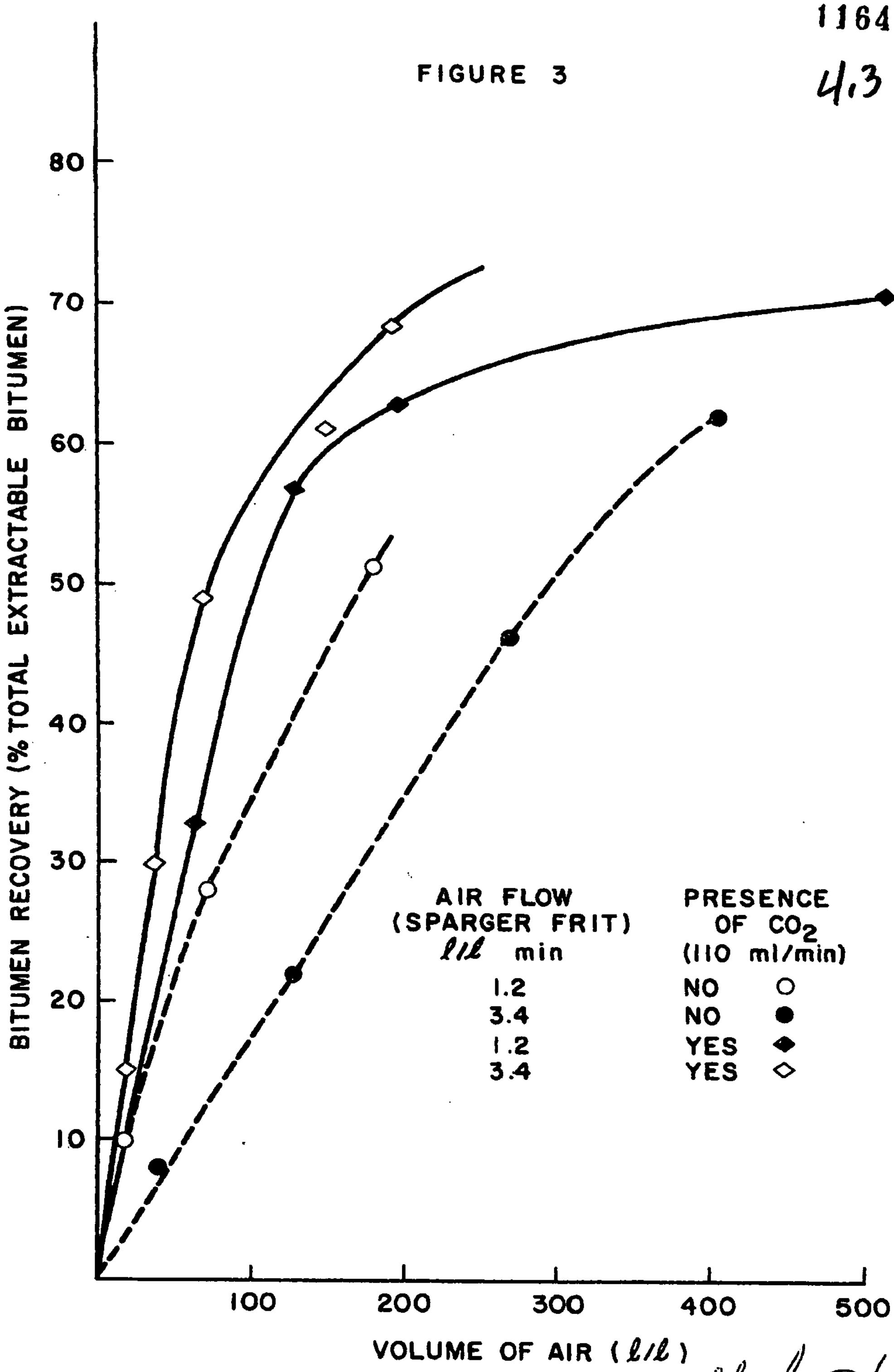
FIGURE 3



E. Stanley Hall

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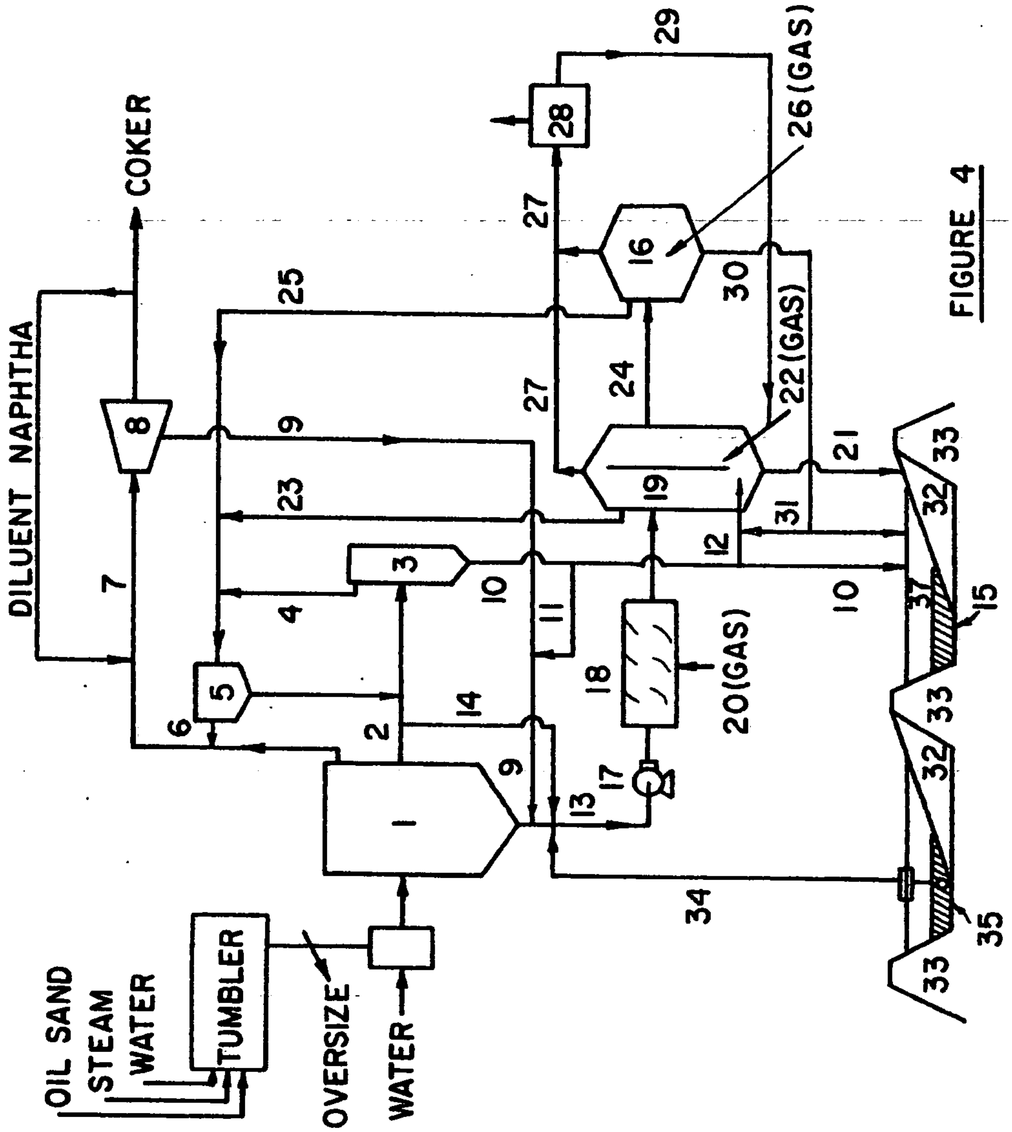

FIGURE 4